Appendix M

Chemical Feed Guidelines

Chemical Feed Guidelines

The following guidelines provide information on the use of water treatment chemicals for coagulation and particle removal. Typical chemicals used for these applications include coagulants, flocculants, and filter aids. To use these chemicals properly, it is necessary to understand how the specific chemicals function and the type of calculations that are required to assure accurate feeding. Although these guidelines focus on coagulation and particle removal, the discussion on determining feed rates and preparing feed solutions applies to other water treatment chemical applications such as corrosion and taste and odor control.

Chemicals for Coagulation and Particle Removal

Coagulation Chemicals

Alum

1. Alum (aluminum sulfate) is one of the most widely used coagulants in water treatment. When alum is added to water, insoluble precipitates such as aluminum hydroxide ($Al(OH)_3$) are formed.

2. The optimum pH range for alum is generally about 5 to 8.

3. Alkalinity is required for the alum reaction to proceed. If insufficient alkalinity is present in the raw water, the pH will be lowered to the point where soluble aluminum ion is formed instead of aluminum hydroxide. Soluble aluminum can cause post flocculation to occur in the plant clearwell and distribution system.

4. As a rule of thumb, about 1.0 mg/L of commercial alum will consume about 0.5 mgIL of alkalinity. At least 5 to 10 mg/L of alkalinity should remain after the reaction to maintain optimum pH.

5. 1.0 mg/L of alkalinity expressed as $CaCO_3$ is equivalent to:
   - 0.66 mg/L 85% quicklime (CaO)
   - 0.78 mg/L 95% hydrated lime ($Ca(OH)_3$)
   - 0.80 mg/L caustic soda ($NaOH$)
   - 1.08 mg/L soda ash (Na_2CO_3)
   - 1.52 mg/L sodium bicarbonate ($NaHCO_3$)

6. If supplemental alkalinity is used it should be added before coagulant addition, and the chemical should be completely dissolved by the time the coagulant is added.

7. When mixing alum with water to make a feed solution, maintain the pH below 3.5 to prevent hydrolysis from occurring which will reduce the effectiveness of the chemical. A 10 to 20 percent alum solution by weight will maintain this pH requirement in most applications.

8. Density and solution strength values for commercial alum can be found in Table M-1. A solution strength of 5.4 lb/gal can be used for approximate chemical calculations.

Ferric Chloride

1. The optimum pH range for ferric chloride is 4 to 12.

2. When mixing alum with water to make a feed make a feed solution, maintain the pH below 2.2.

3. Ferric chloride consumes alkalinity at a rate of about 0.75 mg/L alkalinity for every 1 mg/L of ferric chloride.

4. Ferric chloride dosage is typically about half of the dosage required for alum.

5. Density and solution strength values for commercial ferric chloride vary with the supplier. A solution strength of 3.4 Ib $FeCl_3$/gallon can be used for approximate chemical calculations (i,e., product density of 11.3 Ib/gal and 30 percent $FeCl_3$ by weight).

Table M-1. Densities and Weight Equivalents of Commercial Alum Solutions[1]

Specific Gravity	Density lb/gal	% Al_2O_3	Equivalent % Dry Alum[2]	Strength lb alum/gallon	Strength g alum/liter
1.0069	8.40	0.19	1.12	0.09	11.277
1.0140	8.46	0.39	2.29	0.19	23.221
1.0211	8.52	0.59	3.47	0.30	35.432
1.0284	8.58	0.80	4.71	0.40	48.438
1.0357	8.64	1.01	5.94	0.51	61.521
1.0432	8.70	1.22	7.18	0.62	74.902
1.0507	8.76	1.43	8.41	0.74	88.364
1.0584	8.83	1.64	9.65	0.85	102.136
1.0662	8.89	1.85	10.88	0.97	116.003
1.0741	8.96	2.07	12.18	1.09	130.825
1.0821	9.02	2.28	13.41	1.21	145.110
1.0902	9.09	2.50	14.71	1.34	160.368
1.0985	9.16	2.72	16.00	1.47	175.760
1.1069	9.23	2.93	17.24	1.59	190.830
1.1154	9.30	3.15	18.53	1.72	206.684
1.1240	9.37	3.38	19.88	1.86	223.451
1.1328	9.45	3.60	21.18	2.00	239.927
1.1417	9.52	3.82	22.47	2.14	256.540
1.1508	9.60	4.04	23.76	2.28	273.430
1.1600	9.67	4.27	25.12	2.43	291.392
1.1694	9.57	4.50	26.47	2.58	309.540
1.1789	9.83	4.73	27.82	2.74	327.970
1.1885	9.91	4.96	29.18	2.89	346.804
1.1983	9.99	5.19	30.53	3.05	365.841
1.2083	10.08	5.43	31.94	3.22	385.931
1.2185	10.16	5.67	33.35	3.39	406.370
1.2288	10.25	5.91	34.76	3.56	427.131
1.2393	10.34	6.16	36.24	3.74	449.122
1.2500	10.43	6.42	37.76	3.93	472.000
1.2609	10.52	6.67	39.24	4.12	494.777
1.2719	10.61	6.91	40.65	4.31	517.027
1.2832	10.70	7.16	42.12	4.51	540.484
1.2946	10.80	7.40	43.53	4.71	563.539
1.3063	10.89	7.66	45.06	4.91	588.619
1.3182	10.99	7.92	46.59	5.12	614.149
1.3303	11.09	8.19	48.18	5.34	640.938
1.3426	11.20	8.46	49.76	5.57	668.078
1.3551	11.30	8.74	51.41	5.81	696.657
1.3679	11.41	9.01	53.00	6.05	724.987

[1]From Allied Chemical Company "Alum Handbook", modified by adding gm/L dry alum column.

[2]17% Al_20_3 in Dry Alum + 0.03% Free Al_2O_3.

Polyaluminum Chloride (1)

1. Polyaluminum chloride (PACI) products are less sensitive to pH and can generally be used over the entire pH range generally found in drinking water treatment (i.e., 4.5 to 9.5).

2. Alum and PACl products are not compatible; a change from feeding alum to PACl requires a complete cleaning of the chemical storage tanks and feed equipment.

3. The basicity of the product 'determines its most appropriate application:
   - Low basicity PACls (below 20 percent): Applicable for waters high in color and total organic carbon (TOC).
   - Medium basicity PACls (40 to 50 percent): Applicable for cold water, low turbidity, and slightly variable raw water quality.
   - High basicity PACls (above 70 percent): applicable for waters with high variable quality, as a water softening coagulant, for direct filtration, and some waters with high color and TOC.

4. Check specific manufacturer's product information for density and strength values.

Polymers (Coagulation)

1. Polymer can be added as either the primary coagulant or as a coagulant aid to partially replace a primary coagulant (e.g., alum).

2. Polymers used for coagulation are typically low molecular weight and positively charged (cati-
.............onic).

3. The dosage for polymers used for coagulation is dependent on raw water quality.

4. Product density and solution strength information can be obtained from the individual polymer manufacturers.

Flocculation Chemicals

1. Polymers used as flocculants generally have a high molecular weight and have a charge that is positive, negative (anionic), or neutral (nonionic).

2. The purpose of a flocculant is to bridge and enmesh the neutralized particles into larger floc particles, and they are generally fed at a dosage of less than 1 mg/L.

3. Flocculants should be fed at a point of gentle mixing (e.g., diffuser pipe across a flocculation basin) to prevent breaking apart the long-chained organic molecules.

4. Product* density and solution strength information can be obtained from the individual polymer manufacturers.

Filter Aid Chemicals

1. Polymers used as filter aids are similar to flocculants in both structure and function.

2. Filter aid polymers are typically fed at dosages less than 0.1 mg/L; otherwise, when fed in excess concentrations they can contribute to filter head loss and short filter run times.

3. Filter aid polymers are fed at a point of gentle mixing (e.g., filter influent trough).

4. Product density and solution strength information can be obtained from the individual polymer manufacturers.

Feeding Chemicals in the Plant

Step 1. Determining the Required Chemical Dosage

1. The appropriate chemical dosage for coagulants is typically determined by lab or pilot scale testing le.g., jar testing, pilot plant), online monitoring (e.g., streaming current meter, particle counter), and historical experience. A guideline on performing jar testing is include in Appendix L.

2. Flocculants are typically fed at concentrations less than 1 mg/L. Jar testing can be used to estimate the optimum dosage.

3. The typical dosage for filter aid polymers is less than 0.1 mg/L. Jar testing, including filtering the samples, is typically not effective for determining an optimum dose. The polymer manufacturers can provide guidelines on use of their products as filter aids.

Step 2. Determining the chemical Feed Rate

1. Once the chemical dosage is determined, the feed rate can be calculated by the equation below:

   Feed Rate (lb/day) = Flow Rate (MGD) x Chemical Dose (mg/L) x 8.34 lb/gal

Step 3. Determining the Chemical Feeder Setting

1. Once the chemical feed rate is known, this value must be translated into a chemical feeder setting. The approach for determining the setting depends on whether the chemical is in a dry or liquid form.

2. For dry chemicals, a calibration curve should be developed for all feeders that are used in the plant. A typical calibration curve is shown in Figure M-1. The points on the curve are determined by operating the feeder at a full operating range of settings and collecting a sample of the chemical over a timed period for each setting. Once the sample weight is determined by a balance, the feed rate can be determined for that set point. For example, the feed rate for the 100 setting was determined by collecting a feeder output sample over a 2-minute period. The sample weight was 5.8 lb. The associated feed rate can then be converted into an equivalent hourly feed rate as follows:

$$\text{Feed Rate} = \frac{5.8\ \text{lb}}{2\ \text{min}} \times \frac{60\ \text{min}}{\text{hr}} = \frac{174\ \text{lb}}{\text{hr}}$$

3. For liquid chemicals, a calibration curve should also be developed for all liquid feeders used in a plant. An approach similar to dry feeder calibration is followed; however, a volumetric cylinder is typically used to collect the sample. For example, 50 mL of liquid chemical collected over 2 minutes would equate to a feed rate of 25 mL/min. A graph similar to FigureM-1 can be developed showing pump setting (e.g., % speed) versus feed rate in mL/min.

4. For liquid chemicals, an additional step is necessary to convert the required weight-based feed rate to a volume-based pumping rate. The following equation can be used to determined the pumping rate:

$$\text{Pump Rate (mL/min)} = \frac{(F_R)\ \text{lb}}{\text{day}} \times \frac{\text{gal}}{(C_S)\ \text{lb}} \times \frac{\text{day}}{1{,}440\ \text{min}} \times \frac{3{,}785\ \text{mL}}{\text{gal}}$$

F_R = Feed Rate (lb/day)

C_S = Chemical Strength (lb/gal)

Preparation of Feed Solutions

Liquid solutions of both dry and liquid chemicals are frequently prepared in a plant to prepare the chemical for feeding (e.g., activating polymer) and to allow the feeding of the chemical in an efficient manner. Two examples are presented below to describe approaches for preparing chemical solutions from dry and liquid chemicals.

Preparation of an Alum Feed Solution

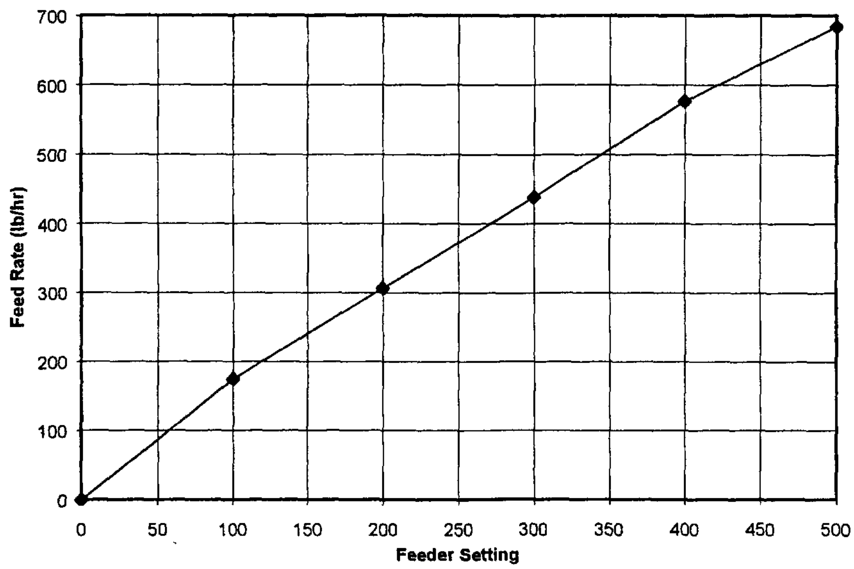
1. Determine the desired percent solution for feeding the alum. As described under the previous alum discussion, a percent solution of 10 to 20 percent is typically used. In this example, assume a 15 percent solution.

2. Based on the volume of alum solution to be prepared, determine the weight of alum to add to the solution tank. For an alum solution volume of 500 gallons, determine the alum weight as follows:

$$\text{Alum Weight} = 500\ \text{gal} \times \frac{8.34\ \text{lb}}{\text{gal}} \times 0.15 = 625\ \text{lb}$$

Figure M-1. Example dry chemical feeder calibration chart.

Setting	Sample Wt. (lb)	Time (minutes)	Feed Rate (lb/hr)
0	0	0	0
100	5.8	2.0	174
200	5.1	1.0	306
300	7.3	1.0	438
400	4.8	0.5	576
500	5.7	0.5	684



3. Determine the alum strength (A_S) for use in calculating feed rates. The alum strength for the example above is calculated as follows:

$$\text{Alum Strength } (A_S) = \frac{625 \text{ lb}}{500 \text{ gal}} = \frac{1.25 \text{ lb}}{\text{gal}}$$

Preparation of a Polymer Feed Solution

1. Polymer manufacturers provide guidelines on preparation of their products, including whether the product is fed neat (i.e., undiluted) or in a diluted form. Diluted polymers are typically mixed at 2% by weight or less; otherwise, they become difficult to mix effectively. For this example, assume a 1% solution is to be prepared.

2. Based on the volume of solution to be prepared, determine the weight of polymer to add to the solution tank. For a solution volume of 200 gallons, determine the polymer weight as follows:

$$\text{Polymer Weight} = 200 \text{ gal} \times \frac{8.34 \text{ lb}}{\text{gal}} \times 0.01 = 16.7 \text{ lb}$$

3. It is frequently easier to measure polymer volumetrically rather than by weight, so the weight of polymer can be converted to an equivalent volume by obtaining the product density from the manufacturer. For example, if the polymer density is 9.5 lb/gal, the volume is calculated as follows:

$$\text{Polymer Volume} = 16.7 \text{ lb} \times \frac{\text{gal}}{9.5 \text{ lb}} = 1.76 \text{ gal}$$

4. Determine the polymer strength (P_S) for use in calculating feed rates. The polymer strength for the example above is calculated as follows:

$$\text{Polymer Strength}(P_S) = \frac{16.7\text{ lb}}{200\text{ gal}} = \frac{0.0835\text{ lb}}{\text{gal}}$$

References

1. Lind, Chris. 1996. "Top 10 Questions about Alum and PACI." Opflow, 22(8):7. AWWA, Denver, CO.